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ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
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PACIFIC AND YUKON REGION
[WEST VANCOUVER, BC]

# MOSQUITO CREEK GOLD MINING CO.
# SITE INSPECTION CONDUCTED
# JUNE 19, 1986

Regional Program Report 87-02

By

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## ABSTRACT

A monitoring program was conducted at Mosquito Creek Mine to assess the impact of tailings pond water on Mosquito Creek and Willow Creek. Samples from mini-piezometres showed contaminated groundwater seepages in Mosquito Creek.

## RÉSUMÉ

Un programme de surveillance fut conduit à la mine Mosquito Creek, pour évaluer l'impact des eaux des étangs de résidus miniers sur le ruisseau Mosquito et la rivière Willow. Des échantillons provenant de piezomètres miniatures ont démontrés une contamination des eaux souterraines s'écoulant vers le ruisseau Mosquito.

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# 1 INTRODUCTION

Mosquito Mine is situated in the Willow River drainage area, a tributary of the Fraser River, about 70 km east of Quesnel (Figure 1). The maximum recorded upstream salmonid migration is 750 chinook which spawn throughout the lower reach of Willow River, 50 miles downstream of Wells (Marshall, 1980). The mine extracted gold and silver from auriferous pyrite and associated free gold with minor galena, sphalerite, cosalite, bismuthinite, schaelite, pyrrhotite, arsenopyrite and chalcopyrite (Hallam, 1980).

The mine operated from January 1980 to June 1984, with periodic working in 1986, processing 50 tons of ore/day and using cyanide for gold extraction. An alkaline-chlorination system was employed for cyanide destruction and heavy metal removal. The tailings were disposed in the tailings pond, built over the old Mosquito Creek bed near the new diverted channel, with the supernatant partially decanted to the polishing pond, partially recycled to the mill and partially exfiltrated to Mosquito Creek.

The Mosquito Creek Gold Mining Company had a long history of cyanide problems associated with a high level of heavy metals in the tailings pond which seeped to Mosquito Creek.

The present study was to monitor the creek conditions in relation the the tailings seepages and document groundwater connections.

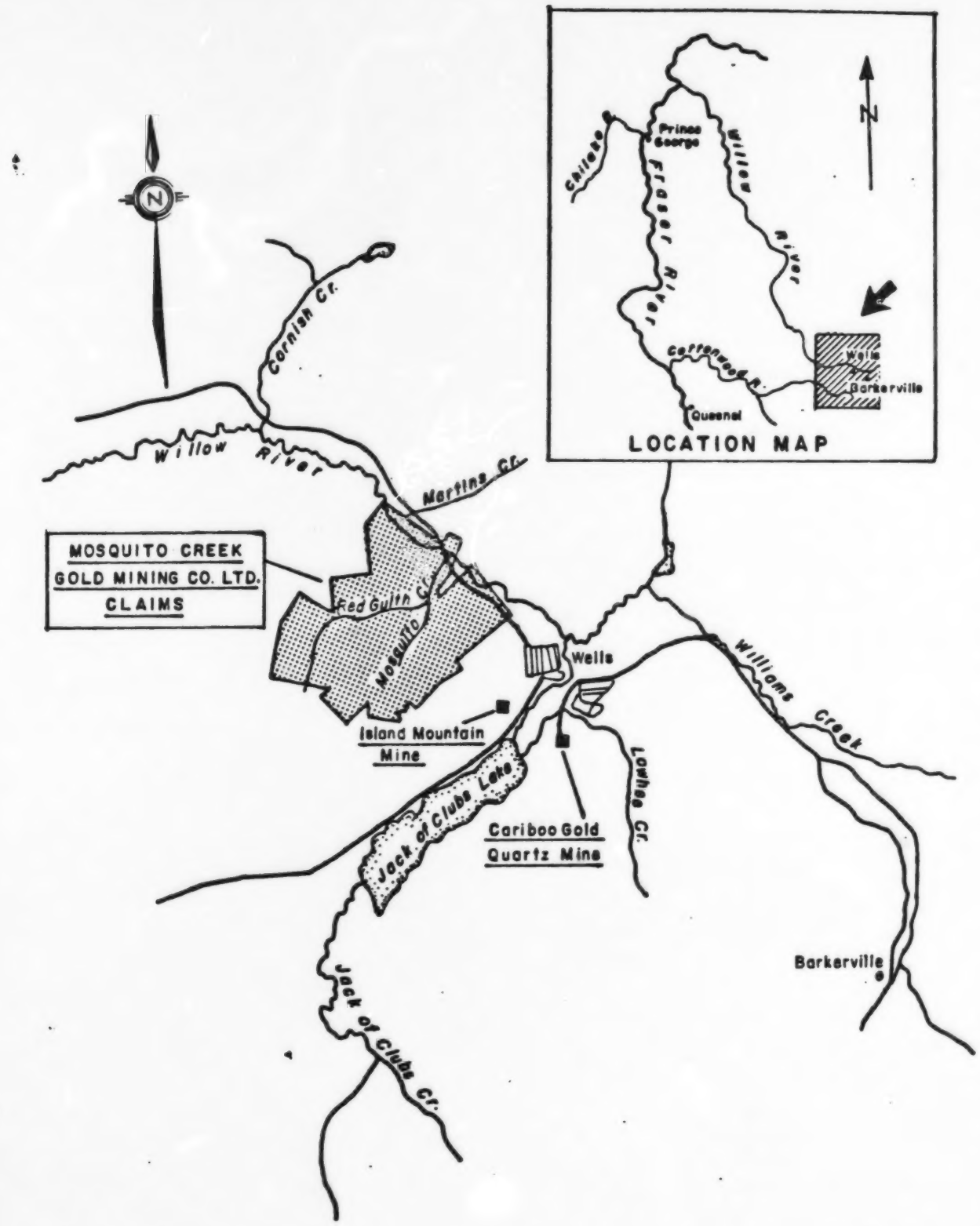


FIGURE 1 LOCATION MAP OF MOSQUITO CREEK GOLD MINING CO. LTD., WELLS, B. C.

## 2 MATERIALS AND METHODS

Water quality chemistry data were collected on June 19, 1986 at 4 stations (Figure 2). Replicated samples were taken at three sites Stations 1, 2, and 4 (Table 1), while Station 3 samples were taken along a transect across the streambed. A well sample was collected using a Van Dorn bottle just below the water surface. Two mini piezometres were lowered into the ground at Station 3. Piezometer 1 was in the center of the creek collecting water 50 cm below the streambed and peizometre 2 was on the left bank 1 m away from the creek in an area where seepages had been previously noticed during high flows. The peizometre was hammered about 75 cm deep into the ground. The water was collected from a tygon tube with the tip protected by fiberglass cloth secured by nylon screen (Lee and Cherry, 1978). The water delivery was assisted with a peristaltic pump at a rate of 100 ml/min.

The following parameters were analyzed for each sample: pH, alkalinity, hardness, conductivity, residues (total, filterable and non-filterable), sulphates, nitrite, nitrates, ammonia, cyanides (total, weak acid dissociable, cyanates and thiocyanites), total and dissolved metals. Hardness was determined from the dissolved sample. The samples for pH, alkalinity, residues, conductivity, sulphate and nitrogen compounds (referred to as "immediates") were kept cool with ice until analyzed. Dissolved metals were filtered the same day through a 0.45 micron cellulose nitrate membrane filter. Total and dissolved metals were preserved with nitric acid (0.5 ml/100 ml) sample. The inductively coupled argon plasma or ICAP scan, an automatic, atomic emissions spectrophotometer, was used for the total and dissolved metal analysis. This scan gives a reading of 26 metals.

Total cyanide samples were collected in 500 ml bottles, preserved with sodium hydroxide pellets and stored in the dark at 4°C. The samples were analyzed at the Environmental Protection (EP) West Vancouver Laboratory with the tetracyanonickelate colorometric method. The detection limit of the analysis is 0.03 mg/l. Buffered samples to pH 5 were used for cyanide weak acid dissociable complexed with nickel and read by colorimetric method. The detection limit is 0.03 mg/l. Thiocyanite samples are complexed with iron

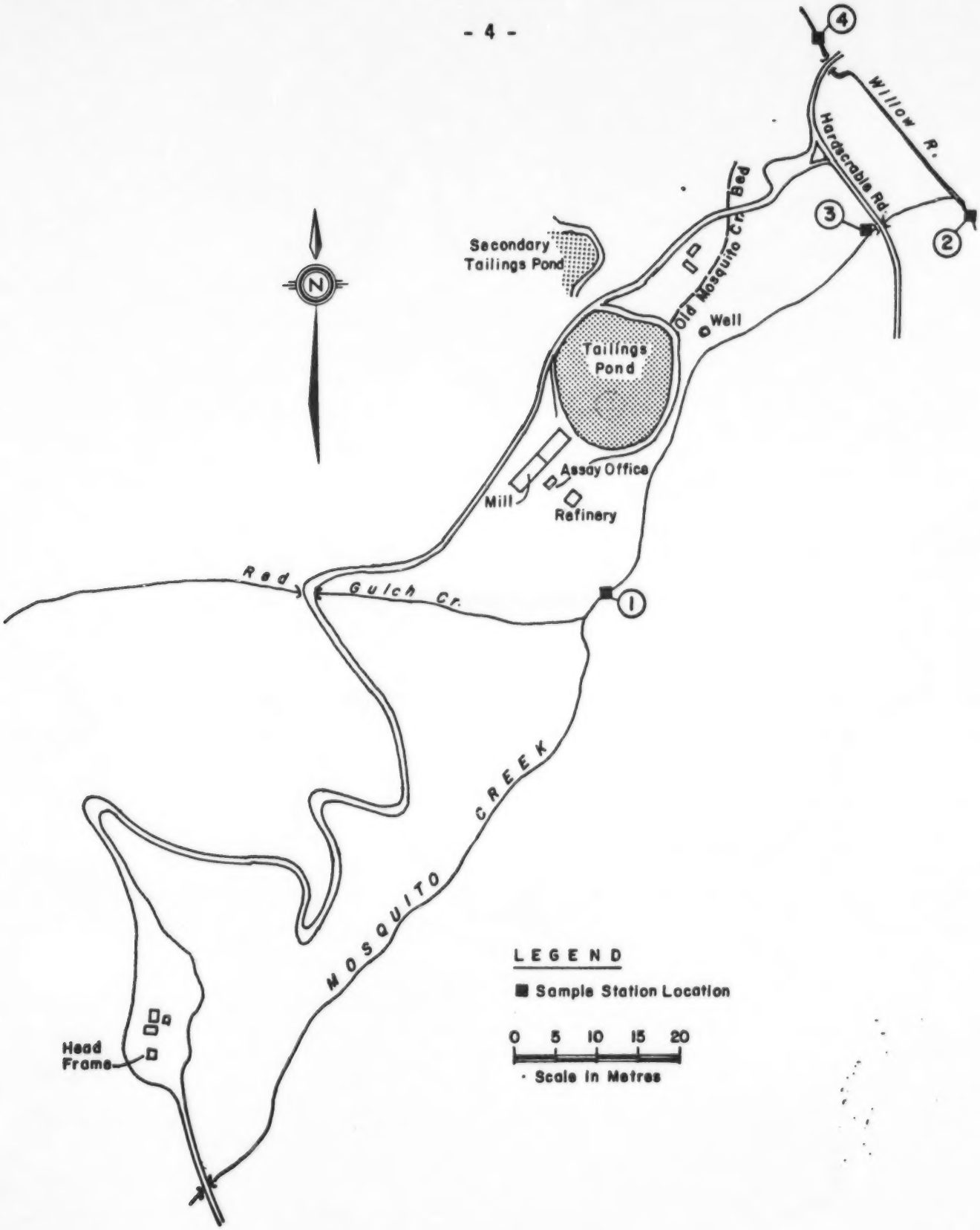


FIGURE 2 MOSQUITO CREEK GOLD MINING CO. LTD., SITE PLAN AND SAMPLE STATION LOCATIONS

and analyzed by colorimetric method. The detection limit is 0.03 mg/l. Cyanates are determined by colorimetric the detection limit is 0.005 mg/l.

TABLE 1 DESCRIPTION OF SAMPLE STATIONS AT MOSQUITO CREEK GOLD MINING CO.

| STATION | LOCATION |
|---|---|
| 1 | On Mosquito Creek d/s of Red Gulch Creek, 20-25 m above the tailings pond and mill. |
| 2 | On Willow River 5 m u/s of Mosquito Creek. |
| 3 | On Mosquito Creek 30-35 m d/s of tailings pond, u/s of road crossing. |
| 4 | On Willow River 30-35 m d/s of Mosquito Creek. |
| Well | Well situated below the tailings dam on the east side of the tailings. |
| Piezo 1 | Piezometre hammered into the streambed 50 cm deep at Station 3 |
| Piezo 2 | Piezometre hammered into the creek bank 1 m away from the creek and 75 cm deep at Station 3. |

## 3 RESULTS AND DISCUSSION

Nine of the 26 metals analysed by the ICAP were not presented in the results tables because they were either all below the detection limit or subject to contamination. Boron levels were all above the detection limits but contamination was found between the dissolved and total metal. No specific pattern could be found. The following metals were below the detection limit both for total and dissolved metal: As (0.05 mg/l), Be (0.001 mg/l), Cr (0.005 mg/l), Ni (0.02 mg/l), Pb (0.02 mg/l), Sb (0.05 mg/l), Se (0.05 mg/l) and V (0.002 mg/l).

### 3.1 Surface Water

All data can be found in Tables 2 (heavy metals) and Table 3 (immediates and cyanides).

**3.1.1 Metals.** No differences were found between total and dissolved metals upstream and downstream of Mosquito Creek and in the Willow River, and between Willow River and Mosquito Creek. The following metals were detectable: barium, cadmium, copper, phosphorus, silicon, tin, strontium, titanium and zinc. The levels were usually very low (Table 2).

Some metal concentrations increased at Station 3 from right to left along the transect. These levels were higher than the upstream station and indicate seepages from the groundwater to Mosquito Creek. These parameters (total values) are the following: calcium (18.3 mg/l on left and 14.6 mg/l on right); iron (0.100 mg/l on left and 0.063 mg/l on right); manganese (0.012 mg/l on left and 0.002 mg/l on right); sodium (1.1 mg/l on left and 0.5 mg/l on right); and hardness (55.8 mg/l on left and 45.2 mg/l on right). The value on the right hand side of the creek bank compared very well with the upstream values indicating that the mixing did not occur across the creek.

High background concentrations of total and dissolved magnesium (3.3 to 3.5 mg/l) and manganese (0.04 to 0.056 mg/l) were found in Willow River when compared to Mosquito Creek. Even though a significant difference between rivers can be found for magnesium the levels were too low to be of concern.

Table 2 Results for Mosquito Creek Mine (Heavy Metals)
June 19, 1986

| STATION NUMBER | Lab. Sample Number | AL TOTICP MG/L | AL DISICP MG/L | BA TOTICP MG/L | BA DISICP MG/L | CA TOTICP MG/L | CA DISICP MG/L | CD TOTICP MG/L | CD DISICP MG/L | CO TOTICP MG/L | CO DISICP MG/L | CU TOTICP MG/L | CU DISICP MG/L | FE TOTICP MG/L | FE DISICP MG/L | MG TOTICP MG/L | MG DISICP MG/L | MN TOTICP MG/L | MN DISICP MG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | repl.1 | <0.05 | <0.05 | 0.012 | 0.013 | 13.2 | 12.9 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.062 | 0.007 | 2.4 | 2.4 | 0.002 | 0.001 |
| 1 | repl.2 | 0.06 | <0.05 | 0.015 | 0.011 | 13.1 | 12.2 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.089 | 0.008 | 2.5 | 2.3 | 0.003 | 0.001 |
| | repl.3 | <0.05 | <0.05 | 0.011 | 0.011 | 13.2 | 12.9 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.062 | 0.008 | 2.5 | 2.4 | 0.002 | 0.001 |
| | AVERAGE | ---- | ---- | 0.013 | 0.012 | 13.2 | 12.7 | ----- | ----- | ----- | ----- | ----- | ----- | 0.071 | 0.008 | 2.5 | 2.4 | 0.002 | 0.001 |
| | STD | ---- | ---- | 0.002 | 0.001 | 0.1 | 0.4 | ----- | ----- | ----- | ----- | ----- | ----- | 0.016 | 0.001 | 0.1 | 0.1 | 0.001 | 0.000 |
| | repl.1 | 0.26 | <0.05 | 0.019 | 0.015 | 14.4 | 14.2 | <0.002 | <0.002 | 0.009 | <0.005 | <0.005 | <0.005 | 0.723 | 0.139 | 3.4 | 3.3 | 0.056 | 0.055 |
| 2 | repl.2 | 0.27 | <0.05 | 0.018 | 0.014 | 14.7 | 14.4 | <0.002 | <0.002 | 0.011 | <0.005 | <0.005 | <0.005 | 0.728 | 0.139 | 3.5 | 3.4 | 0.056 | 0.052 |
| | repl.3 | 0.25 | <0.05 | 0.020 | 0.013 | 14.7 | 14.5 | <0.002 | <0.002 | 0.012 | <0.005 | <0.005 | <0.005 | 0.588 | 0.141 | 3.5 | 3.4 | 0.051 | 0.050 |
| | AVERAGE | 0.26 | ---- | 0.019 | 0.014 | 14.6 | 14.4 | ----- | ----- | 0.011 | ----- | ----- | ----- | 0.680 | 0.140 | 3.5 | 3.4 | 0.054 | 0.052 |
| | STD | 0.01 | ---- | 0.001 | 0.001 | 0.2 | 0.2 | ----- | ----- | 0.002 | ----- | ----- | ----- | 0.079 | 0.001 | 0.1 | 0.1 | 0.003 | 0.003 |
| | left | <0.05 | <0.05 | 0.013 | 0.012 | 18.3 | 17.8 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.100 | 0.044 | 2.8 | 2.7 | 0.012 | 0.017 |
| 3 | centre | 0.07 | <0.05 | 0.015 | 0.011 | 16.0 | 15.9 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.080 | 0.024 | 2.7 | 2.6 | 0.008 | 0.009 |
| | right | 0.06 | <0.05 | 0.012 | 0.011 | 14.6 | 14.2 | <0.002 | <0.002 | <0.005 | <0.005 | <0.005 | <0.005 | 0.063 | 0.010 | 2.5 | 2.4 | 0.002 | 0.003 |
| | AVERAGE | 0.07 | ---- | 0.013 | 0.011 | 16.3 | 16.0 | ----- | ----- | ----- | ----- | ----- | ----- | 0.081 | 0.026 | 2.7 | 2.6 | 0.007 | 0.010 |
| | STD | 0.01 | ---- | 0.002 | 0.001 | 1.9 | 1.8 | ----- | ----- | ----- | ----- | ----- | ----- | 0.019 | 0.017 | 0.2 | 0.2 | 0.005 | 0.007 |
| | repl.1 | 0.28 | 0.06 | 0.022 | 0.016 | 14.8 | 14.5 | <0.002 | <0.002 | 0.012 | <0.005 | <0.005 | <0.005 | 0.783 | 0.147 | 3.5 | 3.4 | 0.056 | 0.055 |
| 4 | repl.2 | 0.16 | <0.05 | 0.018 | 0.011 | 14.8 | 14.4 | 0.002 | <0.002 | 0.010 | <0.005 | <0.005 | <0.005 | 0.519 | 0.142 | 3.5 | 3.3 | 0.046 | 0.040 |
| | repl.3 | 0.18 | <0.05 | 0.018 | 0.013 | 14.7 | 14.3 | <0.002 | <0.002 | 0.006 | <0.005 | <0.005 | <0.005 | 0.554 | 0.143 | 3.5 | 3.3 | 0.046 | 0.048 |
| | AVERAGE | 0.21 | ---- | 0.019 | 0.013 | 14.8 | 14.4 | ----- | ----- | 0.009 | ----- | ----- | ----- | 0.619 | 0.144 | 3.5 | 3.3 | 0.049 | 0.048 |
| | STD | 0.06 | ---- | 0.002 | 0.003 | 0.1 | 0.1 | ----- | ----- | 0.003 | ----- | ----- | ----- | 0.143 | 0.003 | 0.0 | 0.1 | 0.006 | 0.008 |
| WELL | 22 | 0.07 | <0.05 | 0.038 | 0.027 | 48.4 | 46.0 | <0.002 | <0.002 | 0.194 | <0.005 | 0.022 | <0.00 | 21.700 | 0.020 | 6.0 | 5.5 | 0.219 | 0.218 |
| Piezo. # | 23 | 0.18 | <0.05 | 0.030 | 0.024 | 51.0 | 50.4 | <0.002 | <0.002 | 0.006 | 0.006 | <0.00 | <0.00 | 0.637 | 0.317 | 5.7 | 5.5 | 0.024 | 0.017 |
| Piezo. # | 24 | 0.23 | <0.05 | 0.026 | 0.021 | 50.7 | 50.1 | <0.002 | <0.002 | 0.009 | 0.007 | <0.00 | <0.00 | 0.759 | 0.337 | 5.7 | 5.4 | 0.015 | 0.005 |

Continued ...

Table 2 Results for Mosquito Creek Mine (Heavy Metals)
June 19, 1986 (Continued)

| STATION NUMBER | Lab. Sample Number | MO TOTICP MG/L | MO DISICP MG/L | NA TOTICP MG/L | NA DISICP MG/L | P TOTICP MG/L | P DISICP MG/L | SI TOTICP MG/L | SI DISICP MG/L | SN TOTICP MG/L | SN DISICP MG/L | SR TOTICP MG/L | SR DISICP MG/L | TI TOTICP MG/L | TI DISICP MG/L | ZN TOTICP MG/L | ZN DISICP MG/L | HARD. Ca + Mg MG/L | HARD. TOTAL MG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | repl.1 | <0.005 | <0.005 | 0.4 | 0.4 | <0.05 | <0.05 | 2.0 | 1.8 | <0.01 | 0.01 | 0.049 | 0.052 | <0.002 | 0.002 | <0.002 | <0.002 | 42.1 | 42.2 |
| 1 | repl.2 | <0.005 | <0.005 | 0.4 | 0.3 | <0.05 | <0.05 | 2.1 | 1.8 | <0.01 | <0.01 | 0.059 | 0.044 | 0.004 | <0.002 | <0.002 | <0.002 | 39.7 | 39.8 |
| | repl.3 | <0.005 | <0.005 | 0.4 | 0.4 | <0.05 | <0.05 | 1.9 | 1.8 | <0.01 | <0.01 | 0.042 | 0.043 | <0.002 | <0.002 | <0.002 | <0.002 | 42.1 | 42.2 |
| | AVERAGE | ----- | ----- | 0.4 | 0.4 | ---- | ---- | 2.0 | 1.8 | ---- | ---- | 0.050 | 0.046 | ----- | ----- | ----- | ----- | 41.3 | 41.4 |
| | STD | ----- | ----- | 0.0 | 0.1 | ---- | ---- | 0.1 | 0.0 | ---- | ---- | 0.009 | 0.005 | ----- | ----- | ----- | ----- | 1.4 | 1.4 |
| | repl.1 | 0.010 | <0.005 | 0.5 | 0.5 | 0.05 | <0.05 | 1.9 | 1.5 | <0.01 | <0.01 | 0.072 | 0.072 | 0.008 | <0.002 | <0.002 | <0.002 | 48.9 | 49.5 |
| 2 | repl.2 | 0.010 | <0.005 | 0.5 | 0.5 | <0.05 | <0.05 | 1.9 | 1.6 | <0.01 | 0.02 | 0.070 | 0.070 | 0.005 | <0.002 | 0.003 | <0.002 | 49.7 | 50.3 |
| | repl.3 | 0.008 | <0.005 | 0.5 | 0.5 | 0.06 | <0.05 | 1.9 | 1.6 | <0.01 | <0.01 | 0.080 | 0.067 | 0.009 | <0.002 | 0.003 | <0.002 | 50.2 | 50.8 |
| | AVERAGE | 0.009 | ----- | 0.5 | 0.5 | 0.06 | ---- | 1.9 | 1.6 | ---- | ---- | 0.074 | 0.070 | 0.007 | ----- | 0.003 | ----- | 49.6 | 50.2 |
| | STD | 0.001 | ----- | 0.0 | 0.0 | 0.01 | ---- | 0.0 | 0.1 | ---- | ---- | 0.005 | 0.003 | 0.002 | ----- | 0.000 | ----- | 0.7 | 0.7 |
| | left | <0.005 | <0.005 | 1.1 | 1.1 | <0.05 | <0.05 | 1.9 | 1.9 | <0.01 | 0.06 | 0.066 | 0.066 | <0.002 | 0.004 | <0.002 | <0.002 | 55.5 | 55.8 |
| 3 | centre | 0.007 | <0.005 | 1.3 | 0.7 | <0.05 | <0.05 | 1.9 | 1.9 | 0.02 | 0.03 | 0.070 | 0.056 | 0.006 | <0.002 | <0.002 | <0.002 | 50.2 | 50.4 |
| | right | <0.005 | <0.005 | 0.5 | 0.5 | <0.05 | <0.05 | 1.9 | 1.8 | <0.01 | 0.02 | 0.059 | 0.053 | <0.002 | <0.002 | <0.002 | <0.002 | 45.1 | 45.2 |
| | AVERAGE | ---- | ----- | 1.0 | 0.8 | ---- | ---- | 1.9 | 1.9 | ---- | 0.04 | 0.065 | 0.058 | ----- | ----- | ----- | ----- | 50.3 | 50.5 |
| | STD | ---- | ----- | 0.4 | 0.3 | ---- | ---- | 0.0 | 0.1 | ---- | 0.02 | 0.006 | 0.007 | ----- | ----- | ----- | ----- | 5.2 | 5.3 |
| | repl.1 | 0.006 | <0.005 | 0.5 | 0.5 | <0.05 | <0.05 | 2.0 | 1.6 | 0.01 | 0.07 | 0.085 | 0.077 | 0.010 | <0.002 | 0.003 | <0.002 | 50.1 | 50.9 |
| 4 | repl.2 | 0.007 | <0.005 | 0.5 | 0.5 | 0.08 | <0.05 | 1.7 | 1.6 | <0.01 | <0.01 | 0.076 | 0.055 | 0.004 | <0.002 | 0.003 | <0.002 | 49.6 | 50.2 |
| | repl.3 | 0.008 | <0.005 | 0.5 | 0.5 | 0.06 | <0.05 | 1.8 | 1.6 | <0.01 | 0.03 | 0.075 | 0.066 | 0.004 | <0.002 | <0.002 | <0.002 | 49.5 | 50.1 |
| | AVERAGE | 0.007 | ----- | 0.5 | 0.5 | 0.07 | ---- | 1.8 | 1.6 | ---- | 0.05 | 0.079 | 0.066 | 0.006 | ----- | 0.003 | ----- | 49.7 | 50.4 |
| | STD | 0.001 | ----- | 0.0 | 0.0 | 0.01 | ---- | 0.2 | 0.0 | ---- | 0.03 | 0.006 | 0.011 | 0.003 | ----- | 0.000 | ----- | 0.3 | 0.4 |
| WELL | 22 | 0.041 | <0.005 | 1.2 | 1.1 | <0.05 | <0.05 | 2.0 | 1.3 | 0.04 | 0.07 | 0.190 | 0.167 | 0.008 | <0.002 | 0.013 | 0.003 | 138.0 | 138.0 |
| Piezo. # | 23 | 0.010 | <0.005 | 6.7 | 6.6 | <0.05 | <0.05 | 2.4 | 2.2 | <0.01 | 0.02 | 0.207 | 0.182 | 0.006 | <0.002 | 0.003 | 0.002 | 149.0 | 149.0 |
| Piezo. # | 24 | <0.005 | <0.005 | 6.8 | 6.6 | 0.06 | 0.05 | 2.7 | 2.2 | 0.02 | 0.01 | 0.199 | 0.173 | 0.009 | <0.002 | 0.004 | <0.002 | 147.0 | 148.0 |

Table 3 Results for Mosquito Creek Mine (Immediates and Cyanides)
June 19, 1986

| STATION NUMBER | Lab. Sample Number | ALK MG/L | COND UMHO/C | NH3 MG/L | NO2 MG/L | NO3 MG/L | PH REL.U. | SO4 MG/L | T.Res. MG/L | F.Res. MG/L | N.-F.Res MG/L | T. CN MG/L | WAD CN MG/L | CNO MG/L | CNS MG/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | repl.1 | 36 | 90 | <0.005 | <0.005 | 0.077 | 7.8 | 6 | 67 | <67 | <5 | <0.03 | <0.03 | <0.005 | 0.96 |
| 1 | repl.2 | 36 | 89 | <0.005 | <0.005 | 0.081 | 7.7 | 7 | 70 | <70 | <5 | <0.03 | <0.03 | <0.005 | 0.98 |
| | repl.3 | 37 | 89 | <0.005 | <0.005 | 0.081 | 7.7 | 6 | 58 | <58 | <5 | <0.03 | <0.03 | <0.005 | 0.49 |
| | AVERAGE | 36 | 89 | --- | --- | 0.080 | 7.7 | 6 | 65 | -- | -- | -- | -- | -- | 0.81 |
| | STD | 1 | 1 | --- | --- | 0.002 | 0.1 | 1 | 6 | -- | -- | -- | -- | -- | 0.28 |
| | repl.1 | 40 | 103 | <0.005 | <0.005 | <0.005 | 7.6 | 8 | 81 | 72 | 9 | <0.03 | <0.03 | <0.005 | 4.34 |
| 2 | repl.2 | 40 | 103 | <0.005 | <0.005 | <0.005 | 7.5 | 8 | 85 | 72 | 13 | <0.03 | <0.03 | <0.005 | 3.98 |
| | repl.3 | 40 | 103 | <0.005 | <0.005 | <0.005 | 7.5 | 9 | 81 | <81 | <5 | <0.03 | <0.03 | <0.005 | 1.21 |
| | AVERAGE | 40 | 103 | --- | --- | --- | 7.5 | 8 | 82 | 72 | 11 | -- | -- | -- | 3.18 |
| | STD | 0 | 0 | --- | --- | --- | 0.1 | 1 | 2 | 0 | 3 | -- | -- | -- | 1.71 |
| | left | 42 | 125 | 0.008 | <0.005 | 0.105 | 7.7 | 13 | 84 | <84 | <5 | 0.07 | <0.03 | 0.030 | 2.97 |
| 3 | centre | 42 | 107 | <0.005 | <0.005 | 0.073 | 7.7 | 8 | 71 | <71 | <5 | 0.04 | <0.03 | 0.060 | 6.89 |
| | right | 40 | 97 | <0.005 | <0.005 | 0.045 | 7.7 | 7 | 62 | <62 | <5 | <0.03 | <0.03 | <0.005 | 1.06 |
| | AVERAGE | 41 | 110 | --- | --- | 0.074 | 7.7 | 9 | 72 | -- | -- | 0.06 | -- | 0.045 | 3.64 |
| | STD | 1 | 14 | --- | --- | 0.030 | 0.0 | 3 | 11 | -- | -- | 0.02 | -- | 0.021 | 2.97 |
| | repl.1 | 41 | 103 | 0.006 | <0.005 | <0.005 | 7.6 | 9 | 71 | 61 | 10 | <0.03 | <0.03 | <0.005 | 7.10 |
| 4 | repl.2 | 41 | 103 | 0.008 | <0.005 | <0.005 | 7.6 | 9 | 89 | 74 | 15 | <0.03 | <0.03 | <0.005 | 4.82 |
| | repl.3 | 41 | 103 | 0.006 | <0.005 | <0.005 | 7.5 | 9 | 88 | 77 | 10 | <0.03 | <0.03 | 0.360 | 0.54 |
| | AVERAGE | 41 | 103 | 0.007 | --- | --- | 7.6 | 9 | 83 | 71 | 12 | -- | -- | - | 4.15 |
| | STD | 0 | 0 | 0.001 | --- | --- | 0.1 | 0 | 10 | 9 | 3 | -- | -- | - | 3.33 |
| WELL | | 118 | 280 | 0.011 | <0.005 | 0.032 | 7.2 | 21 | 218 | 177 | 41 | <0.03 | <0.03 | 0.018 | 2.41 |
| Piezo. # | 1 | 98 | 325 | 0.009 | <0.005 | 1.040 | 7.5 | 58 | 217 | 207 | 10 | -- | 0.06 | 0.078 | 4.94 |
| Piezo. # | 2 | 88 | 320 | 0.005 | <0.005 | 0.780 | 7.5 | 58 | 237 | 221 | 16 | 0.39 | 0.05 | 0.882 | 0.64 |

A greater difference exists between manganese values from Willow Creek and Mosquito Creek (ranging from .049 to .056 for Willow to 0.001 to 0.012 mg/l for Mosquito). The source of manganese input in Willow River is not known.

Aluminum, iron, molybdenum and cobalt were found to be high in the total form compared to the dissolved form in Willow River. These levels can be associated with the suspended solids fraction which is higher in the River (9-15 mg/l) when compared to Mosquito Creek (< 5 mg/l).

**3.1.2 Immediates.** No differences for alkalinity, pH, filterable residue and nitrite (Table 3) could be found upstream and downstream in both Mosquito Creek and Willow River. Neither was there any differences between the two receiving water bodies.

Some parameters were found to increase at Station 3 from right to left along the transect. These levels were higher than the upstream station and indicate seepages from the groundwater to the receiving water. These parameters are the following: conductivity (125 umhos/cm on left and 97 umhos/cm on right); sulphates (13 mg/l on left and 7 mg/l on right); and total residue (84 mg/l on left and 62 mg/l on right). Nitrates were higher on the left bank with 0.105 mg/l than the right bank with 0.045 mg/l, while this level was smaller than the average upstream level at Station 1 (0.080 mg/l). The ammonia concentration was higher on the left (0.008 mg/l) compared to the other side (< 0.005 mg/l). Ammonia also increased downstream of Mosquito Creek on Willow River at Station 4 (average 0.007 mg/l). Ammonia can be produced by degradation of thiocyanate and cyanates under acid conditions.

## 3.2 Cyanide Compounds

No difference in cyanide weak acid dissociable could be found between the different stations since all receiving water samples were below the detection limit of 0.03 mg/l. This analysis, which gives a fairly accurate estimate of the toxic component (free cyanide), suggests no acute toxicity from cyanide at that moment. Detectable total cyanide could only be found at Station 3 where a higher concentration was reported on the left side of the creek at 0.07 mg/l.

Cyanate levels were also detected at Station 3 with the highest concentration found in the middle of the creek with 0.060 mg/l. Cyanates were formed when the mine effluents was treated by alkaline chlorination (APHA et al., 1985). This indicates seepage from the tailings pond which contain high levels of different cyanide compounds. The introduction of cyanates seemed to be recent to the receiving water because cyanates in neutral or low pH is unstable and degrade in carbonates and ammonia (APHA et al., 1985). A high cyanate content was found at Station 4 with one of the replicates (0.360 mg/l). This replicate may indicate contamination, an unmixed plume of water from Mosquito Creek or a fresh seepage from the tailings pond emerging in Willow River. This seepage may follow the old Mosquito Creek bed before entering Willow Creek.

Thiocyanate levels were detectable in all samples. The average for the control station was 0.81 mg/l on Mosquito Creek with a 35% coefficient of variability while it was 3.18 mg/l on Willow River with a 53% coefficient of variability. This could be caused by the two abandoned gold mines upstream of Mosquito Creek. An increase of thiocyanate concentration was found in the middle of the creek with 6.89 mg/l at Station 3. Due to the high background variability no differences could be found. At Station 4, a high value of 7.10 mg/l was found but with a 80% coefficient of variability, no cause effect relationship can be attributed. Levels of thiocyanate were well below the toxicity level for Rainbow trout (96 h $LC_{50}$ = 518 mg/l, Heming, et al., 1985).

## 3.3 Groundwater

All results for groundwater analysis (Piezometre #1 and #2) can be found in Tables 2 and 3.

**3.3.1 Metals.** Analysis of the well sample revealed differences between the total and dissolved values for aluminum, cobalt, iron, molybdenum, copper and zinc. The first four elements were identified in the surface water section as being high in the total fraction in Willow River (Station 2 and 4) caused by a higher portion of non-filterable residues. Here also the NFR value was high with 41 mg/l compared to two other groundwater samples, piezometre 1 and 2 (Station 3) with only 10 and 16 mg/l, respectively. These same total metals and manganese were higher when

compared with the piezometres samples. Dissolved iron in the well was very low in comparison to the piezometres samples. This suggests using the dissolved fraction when discussing the results to avoid great discrepancies in groundwater results.

Groundwater metals did not seem to change from the surface water values on Station 3 for metals, indicating no significant increase in the receiving water. These dissolved metals were aluminum, cadmium, cobalt, copper, molybdenum, phosphorus, silicon, tin, titanium and zinc. Barium and strontium had dissolved groundwater concentrations two times (0.024 mg/l) and three times (0.173 mg/l) higher than the surface water at Station 3.

The evidence of groundwater seepage indicated in the receiving water by specific metals were expressed by the same metals in the piezometre samples. Groundwater samples were a few times higher than the receiving water for calcium (3 times, average 48.8 mg/l); iron (8.5 times, average 0.22 mg/l); manganese (8 times, average 0.08 mg/l), sodium (6 times, average 4.77 mg/l); and hardness (3 times, average 145 mg/l).

The tailings pond dissolved copper concentration was 0.2 mg/l (P. Mehling, pers. comm.) compared to 0.02 mg/l in the well and below the detection limit of 0.005 mg/l in the piezometres. The same thing happened with sodium where the tailings pond contains five times (2.9 mg/l, P. Mehling, pers. comm.) the concentration in the groundwater samples and zinc with 10 times (0.025 mg/l, P. Mehling, pers. comm.) the concentration in the groundwater samples. These were the major discrepancies and all the other groundwater metal concentrations from piezometres correspond more or less with the tailings pond concentrations.

3.3.2 Immediates. Only the ammonia level was the same in the groundwater (0.008 mg/l) to one of the receiving water sample at Station 3. All the other parameters were two to five times higher in groundwater than the recieving water at that station based on an average: alkalinity (2.5 times, 101 mg/l); conductivity (2.8 times, 308 umhos/cm); nitrates (8.4 times, 0.62 mg/l); total residue (3 times, 224 mg/l); and sulphates (5 times, 46 mg/l). Nitrite and pH were similar.

Ammonia concentrations in the tailings pond was significantly higher with 1.17 mg/l (100 times groundwater values). This could be a result of cyanate and thiocyanate degradation.

## 3.4 Cyanide Compounds

A higher total cyanide level was found in the piezometre 2 sample (0.39 mg/l) compared to the well (< 0.03 mg/l). The cyanide weak acid dissociable was also higher (0.06 and 0.05 mg/l) in piezometres. The cyanate and thiocyanate levels were different between piezometre 1 (in the streambed) and 2 (in the streambank), with CNO = 0.078 and 0.882 mg/l respectively and CNS = 4.94 and 0.64 mg/l respectively. Except for total cyanide in piezometre 2 where the tailings pond concentrations were similar, all other cyanide compounds were higher in the tailings pond. The cyanide weak acid dissociable was five to six times higher with 0.38 mg/l, cyanates twenty times higher with 8.5 mg/l and thiocyanate two times higher with 4.3 mg/l.

Total cyanide collected from tailings intertidal waters from the tailings pond (P. Mehling, pers. comm.) showed levels of 42.3 mg/l and 27.3 mg/l, with cyanide weak acid dissociable level of 1.25 mg/l and 3.45 mg/l. It seems that the water quality of the tailings ponds do not give the exact picture of the cyanide contamination. Much of it would be found in the interstitial water of tailings sediments. An increase in precipitation would help dilute the level in the tailings ponds but also increase the hydraulic pressure which would increase the groundwater movement towards the receiving waters. It is therefore expected to have an increase of contaminant release during high runoff periods.

# 4 CONCLUSIONS

1. Contamination from groundwater seepages found at Station 3 were indicated through increases of various parameters along the creek transect.

2. Unexpected high cyanate level was found in one of the Willow River replicates downstream of Mosquito Creek. This could indicate other seepage patterns.

3. High cyanide content in tailings interstitial water was found which may cause a problem in the receiving water during high water flow through groundwater seepages.

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